Talk Titles and Abstracts of Zhejiang University-Moscow State University of Lomonosov United International Symposium on Quantum Information and Quantum Algorithms

Non-Abelian observable-geometric phases and quantum computation

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Abstract: In this talk, we report that the notion of non-Abelian observable-geometric phases is introduced, which explicitly exhibits the geometry of a quantum evolution in terms of a fiber bundle based on the observable space. The non-Abelian observable-geometric phases can be used to realize geometric quantum computation, that is, each of quantum gates realized by the non-Abelian observable-geometric phases depends only on the geometry of the observable space. It is shown that the non-Abelian observable-geometric phases realize a universal set of quantum gates in quan-

tum computation. This scheme leads to the same gates as the non-Abelian geometric gates of Sjöqvist et al, but based on the quantum geometry of the observable space beyond the state space.

Implementation of search algorithms - reducing complexity

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Abstract: In this talk, we analyze our efforts in implementation of Grover's search and detection of marked vertex in a binary tree. First, we consider the improvement of the implementation of the operation $I - 2|0\rangle\langle 0|$ proposed in Classical and Quantum Computation by A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi. Improved implementation allows us to reduce the number of qubits needed by one and to lower the number of control qubits in multi-qubit operations. Then, we consider implementation of an algorithm "detection of marked vertex in a binary tree" proposed by A. Montanaro. We consider the possibilities to reduce the number of required qubits by keeping the implementation efficient in number of gates. Main intermediate goal was to ensure larger-scale ex-

periments on notebook simulator of quantum circuits. Side-effect realization was that Qiskit functionality of control qubit attachment is much less resource-efficient than manual implementation of operations, controlled by a qubit.

Quantum information related physics and mathematics

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Abstract: We introduce some progresses in quantum information processing and quantum computation, including quantum coherence, quantum correlations, quantum uncertainty relations, as well as quantum algorithms.

Quantifying the entanglement of quantum channel

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Abstract: We investigate the entanglement of quantum channels. In other words, we discuss the ability of channels to generate and increase the entanglement of quantum states. In the framework of

resource theory of quantum channel, we present three new entanglement measures of channels for a quantum system of arbitrary finite dimension, based on the Choi relative entropy of channels, concurrence and k-ME concurrence, respectively. Rigorous proofs show that these proposed measures fulfill all the requirements dictated by the resource theory of quantum channels, including nonnegativity, weak monotonicity, strong monotone, convexity, additivity, and subadditivity. Comparing with other known measures of the quantum channels, these measures have obvious advantage in computability. According to the power of generating entanglement, we give a classification of quantum channels. Moreover, we provide several examples that characterize the properties of quantum channels and the conversions between quantum coherence states and entangled states and between fully separable states and multipartite entangled states.

A computable multipartite multimode Gaussian quantum correlation measure and the monogamy relations for continuous-variable system

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Abstract: In this talk, definitions of the unification condition, the hierarchy condition and three kinds of monogamy relations for multipartite quantum correlation measures are given and discussed. A computable multipartite multimode Gaussian quantum correlation measure $\mathcal{M}^{(k)}$ is proposed for any k-partite multimode continuous-variable systems with $k \geq 2$. The value of $\mathcal{M}^{(k)}$ only depends on the covariance matrices of continuous-variable states, is invariant under any permutation of subsystems, has no ancilla problem, is nonincreasing under k-partite local Gaussian channels (particularly, invariant under k-partite locally Gaussian unitary operations), and vanishes on k-partite product states. For a k-partite Gaussian state ρ, $\mathcal{M}^{(k)}(\rho) = 0$ if and only if ρ is a k-partite product state. Moreover, $\mathcal{M}^{(k)}$ satisfies the unification condition and the hierarchy condition that a multipartite quantum correlation measure should obey. We also show that $\mathcal{M}^{(k)}$ is not strongly monogamous, but completely monogamous and tightlymonogamous.

Some problems in the effective realization of $\mathcal{PT}$-symmetric systems

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Abstract: In this talk, we first briefly introduce the elements of $\mathcal{PT}$-symmetric theory. Then, we talk about some of our recent works on the effective realization $\mathcal{PT}$-symmetric quantum systems. This problem is tightly related to the dilation technique in mathematics, which will be investigated in both time independent and dependent cases. In particular, we will discuss a solvable dilation model of time dependent $\mathcal{PT}$-symmetric systems. For this model, the metric operators and the dilated Hermitian Hamiltonians can be obtained by using special functions. For an arbitrary finite time interval, such $\mathcal{PT}$-symmetric systems can be simulated. In addition, we will discuss the internal nonlocality for dilated Hermitian Hamiltonians in the time independent case. Different correlation bounds are obtained, which can help in the verification of $\mathcal{PT}$-symmetric systems. At the end of this talk, we briefly look at some potential applications of $\mathcal{PT}$-symmetric theory in the field of quantum circuits and computer.

On Quantum Algorithms for String Processing

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Abstract: In the talk we discuss several problems on string processing and quantum algorithms for them. We start with simple problems and data structures like the string sorting problem where we can obtain quantum speed-up and tree-based data structures for strings. We show that the suggested quantum algorithm for sorting strings is almost optimal up to log-factor. Then, we continue with quantum algorithms for several variants of The Shortest Superstring Problem or Text Assembling from Dictionary Problem with different restrictions. These algorithms can be used in bioinformatics as possible solutions for DNA Assembling problem. Finally, we discuss the Quantum Algorithm for Dyck Language with Multiple Types of Brackets.

Quantum technologies: State of art and perspectives

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Abstract: The talk reports the current state and prospects of the interdisciplinary field of knowledge - Quantum Information Processing and Computation (QIPC). Basically, QIPC includes three large sections: quantum computation, quantum communications, and quantum information science.

The report will consider general and some special issues related to the theoretical and experimental aspects of QIPC mainly related to quantum computation, quantum communications.

The focus is on the main technologies of QIPC developed in the world, and particular in the Russian Federation, which potentially lead or have already led to the creation in the near future of quantum simulators and quantum communication systems.

In the field of quantum computation/simulators, these are technologies that exploit neutral atoms and ions in traps as working physical systems, superconducting systems, impurity structures,

and linear optical systems. In the field of quantum communication - is the creation of a global network based on fiber-optic, atmospheric and space channels.

Separately, the main problems of the implementation of certain nodes/elements of the systems of quantum simulators and quantum coupling are considered.

Quantum circuit complexity

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Abstract: Quantum circuit complexity - a measure of the minimum number of gates needed to implement a given unitary transformation - is a fundamental concept in quantum computation, with widespread applications ranging from determining the running time of quantum algorithms to understanding the physics of black holes. In this talk, I will introduce our recent results on quantum circuit complexity via quantum resource and quantum wasserstein distance. This talk is based on my recent works (arXiv:2204.12051, 2208.06306), joint together with Arthur Jaffe, Seth Lloyd, Kaifeng Bu, Dax Koh, Roy Garcia.

Magic Resource in Stabilizer Formalism of Quantum Computation

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Abstract: In the stabilizer formalism of quantum computation, stabilizer states serve as classical objects, while magic states (non-stabilizer states) serve as quantum resource for promoting stabilizer circuits to universal fault-tolerant quantum computation. Characterization, detection and quantification of magic resource are of basic interest in this paradigmn, and various quantifiers of magic have been introduced in the literature. However, most of them are quite difficult to calculate even numerically, or are restricted to systems of special dimensions. In this talk, we present a quantifier of magic in terms of characteristic functions (Fourier transforms, Weyl transforms) of quantum states, and reveal its basic features and physical significance. This quantifier of magic is easy to compute and well defined in any dimension. We illustrate the effectiveness of this quantifier in detecting magic. Employing this quantifier, we show that the group covariant symmetric informa-

tionally complete (SIC) states possess the maximal magic. Finally, we compare the quantifier of magic with some other existing ones including the well known sum negativity.

Three principles of quantum computing

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Abstract: The point of building a quantum computer is that it allows to model living things with predictive power and gives the opportunity to control life. Its scaling means not just the improvement of the instrument part, but also, mainly, mathematical and software tools, and our understanding of the QC problem. The first principle of quantum modeling is the reduction of reality to finite-dimensional models similar to QED in optical cavities. The second principle is a strict limitation of the so-called Feynman principle, the number of qubits in the standard formulation of the QC. This means treating decoherence exclusively as a limitation of the memory of a classical modeling computer, and introducing corresponding progressive restrictions on the working area of the Hilbert space of quantum states as the model expands. The third

principle is similarity in processes of different nature. The quantum nature of reality is manifested in this principle; its nature is quantum nonlocality, which is the main property that ensures the prospects of quantum physical devices and their radical advantage over classical ones.

Steering Witness and Steering Criterion of Gaussian States

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Abstract: Quantum steering is an important quantum resource, which is intermediate between entanglement and Bell nonlocality. In this paper, we study steering witnesses for Gaussian statesin continuous-variable systems. We give a definition of steering witnesses by covariance matricesof Gaussian states, and then obtain a steering criterion by steering witnesses to detect steerabilityof any (m+n)-mode Gaussian states. In addition, the conditions for two steering witnesses to becomparable and the optimality of steering witnesses are also discussed.

Distributed Quantum Algorithms

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Abstract: It is almost 1000 logical qubits for a universal quantum computer to be used in practice, but this is very difficult nowadays. However, distributed quantum computing (DQC) is likely an important way to overcome this difficult in a way, so this subject has attracted significant attention. In QDC, a complex problem is divided into multi-problems, and then multi-quantum processors solve each problem, respectively (they may have entanglement or be separately), and connected with networks. Such a efficiency equals a large-scale quantum computer. In this talk, we outline a number of distributed quantum algorithms, including distributed quantum algorithm for Simon' problem, distributed Grover' algorithm, distributed Shor' algorithm, and distributed Deutsch-Jozsa algorithms. In addition, we show their advantages by comparing with usual quantum algorithms and distributed classical algorithms.

Quantum Kernel Function Expansion And Hamiltonian Simulations

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Abstract: In this report, I will firstly present my recent work on quantum algorithms. This algorithm, QKFE, focuses on finite temperature quantum simulations. Computing finite temperature properties of a quantum many-body system is key to describing a broad range of correlated quantum many-body physics from quantum chemistry and condensed matter to thermal quantum field theories. Key quantities like partition functions, thermal entropy and free energy can be directly gained by our algorithm. As compared to its classical counterpart, namely the kernel polynomial method (KPM), QKFE has an exponential advantage in the cost of both time and memory. In low temperature regime, QKFE becomes inefficient, as similar to KPM. To resolve this difficulty, we further construct a thermal ensemble iteration (THEI) protocol, which starts from the trivial limit of infinite temperature ensemble and approaches the low temperature regime step-by-step. For

quantum Hamiltonians, whose ground states are preparable with polynomial quantum circuits, THEI has an overall polynomial complexity. We demonstrate its efficiency with applications to one and two-dimensional quantum spin models, and a fermionic lattice. Furthermore, algorithm realization with digital and analogue quantum devices are considered. Concise comparison on present digital and analogue quantum platforms will be given， where it can be seen that analog Hamiltonian simulation is more preferable in terms of present conditions. Based on this, analog Hamiltonian simulation, will be introduced as the last part. In this part, rigorous mathematical definition about analog Hamiltonian simulation will be provided. Besides, universal Hamiltonians, one crucial concept in Hamiltonian simulation field, will be introduced. One compact criterion to judge the “universal” property will be given. And the connection between universal Hamiltonians and computing complexity will be shown. In the end of this report, I will show individual considerations and prospects on this field.

Finding out all locally indistinguishable sets of generalized Bell states

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Abstract: In general, for a bipartite quantum system $\mathbf{C}^d \otimes \mathbf{C}^d$ and an integer k such that $4 \leq k \leq d$, there are few necessary and sufficient conditions for local discrimination of sets of k generalized Bell states (GBSs) and it is difficult to locally distinguish k-GBS sets. The purpose of this talk is to explain how to completely solve the problem of local discrimination of GBS sets in some bipartite quantum systems. Firstly three practical and effective sufficient conditions are given, Fan and Wang et al. results [Phys Rev Lett 92, 177905 (2004); Phys Rev A 99, 022307 (2019)] can be deduced as special cases of these conditions. Secondly in $\mathbf{C}^4 \otimes \mathbf{C}^4$, a necessary and sufficient condition for local discrimination of GBS sets is provided, and a list of all locally indistinguishable 4-GBS sets is provided, and then the problem of local discrimination of GBS sets is completely solved. In $\mathbf{C}^5 \otimes \mathbf{C}^5$, a concise necessary and sufficient condition for one-way local discrimination of GBS sets is obtained, which gives an affirmative answer to the case $d = 5$ of the problem proposed by Wang et al.

One-excitation state transfer along zigzag and alternating chains under XXZ-Hamiltonian with dipole-dipole interaction. M-neighbor approximation

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Abstract: We study the one-excitation pure state transfer along the N-node zigzag and alternating spin chains governed by the XXZ-Hamiltonian with the dipole-dipole interaction using the M-neighbor ($M \geq 1$) approximation. We show that the nearest neighbor approximation is not applicable to such interaction, i.e., always $M > 1$. Moreover, the dynamics along the alternating chain can not be approximated by the M-neighbor interaction unless $M = N - 1$ (all-node interaction). There is a region in the parameter space characterizing the chain geometry and orientation where the high-probability state-transfer can be established. We compare the optimal state-transfer probabilities and appropriate time instants for the zigzag and alternating chains.

Detection of entanglement using $\mathcal{PT}$-moments

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Abstract: Although quantum entanglement is an important resource, its characterization is quite challenging. The partial transposition is a common method to detect bipartite entanglement. In this paper, the authors study the partial-transpose $\mathcal{PT}$-moments of two-qubit states, and completely describe the whole region, composed of the second and third $\mathcal{PT}$-moments, for all two-qubit states. Furthermore, they determine the accurate region corresponding to all entangled two-qubit states. The states corresponding to those boundary points of the whole region, and to the border lines between separable and entangled states are analyzed. As an application, they characterize the entangled region of $\mathcal{PT}$-moments for the two families of Werner states and Bell-diagonal states. The relations between entanglement and the pairs of $\mathcal{PT}$-moments are revealed from these typical examples. They also numerically plot the whole region of possible $\mathcal{PT}$-moments for all two-qubit X-states, and find that this region is almost the same as the whole region of $\mathcal{PT}$-moments for all two-qubit states. Moreover, they extend their results to detect the entanglement of multiqubit states. By utilizing the $\mathcal{PT}$-moment-based method to

characterize the entanglement of the multiqubit states mixed by the GHZ and W states, they propose an operational way of verifying the genuine entanglement in such states.